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WASTE WOOD AND BULKY REFUSE DISPOSAL ST. LOUIS FACILITIES

Saint Louis City, Missouri

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The objectives of the project were to: (1) determine the quantities of waste wood produced by the Park and Forestry Department of a major city; (2) determine the quantities of bulky burnable objects produced by a major city; (3) demonstrate the feasibility of effecting conservation of waste wood by reclamation as a useful product; (4) demonstrate the feasibility of assisting in human rehabilitation by using City Workhouse inmates to prepare pulpwood and to effect size reduction of bulky, burnable objects; (5) demonstrate the feasibility of effecting size reduction of bulky, burnable objects in a facility not located at a public refuse incinerator. The report describes and evaluates the equipment used, personnel problems encountered, details the costs incurred, and provides conclusions and recommendations.

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WASTE WOOD AND BULKY REFUSE DISPOSAL

St. Louis Facilities

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U.S. ENVIRONMENTAL PROTECTION AGENCY

1974

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FACILITIES FOR DISPOSAL OF WASTE WOOD AND BULKY OBJECTS

CITY OF ST. LOUIS, MISSOURI

PROJECT HISTORY

In August, 1967, the City of St. Louis, Missouri, made application to the Bureau of Solid Waste Management for a grant-in-aid to partially support the construction and operation of facilities to assist in the disposal of large tree trunks and branches and of bulky refuse. The City was notified of approval and funding of the project in March 1968, with notice to proceed with the project as of April 1, 1968.

Design and construction of the fixed equipment and facilities originally were scheduled for completion by April 1, 1969. Because of strikes and unforeseen complexities in providing power service and in general construction, the facilities were not substantially completed until November 1969. A trial run on December 1, 1969, disclosed several minor deficiencies which required correction before the equipment could be placed in full operation. Informal operations were begun in April 1970, with formal operation beginning on June 1, 1970. The operating phase of the demonstration project continued until March 31, 1972.

PROJECT OBJECTIVES

The project objectives of the solid waste disposal demonstration were as follows:

1. To determine the quantities of waste wood produced by the Park and Forestry Department of a major City.

2. To determine the quantities of bulky burnable objects produced by a major City.

3. To demonstrate the feasibility of effecting conservation of waste wood by reclamation as a useful product.

4. To demonstrate the feasibility of assisting in human rehabilitation by using City Workhouse inmates for the preparation of pulpwood and in effecting size reduction of bulky burnable objects.

5. To demonstrate the feasibility of preparing waste wood (logs and tree trimmings) for sale as pulpwood.

6. To demonstrate the feasibility of effecting size reduction of bulky burnable objects in a facility not located at a public refuse incinerator.

PROJECT NEED AND BACKGROUND

Few data are available regarding the quantities and types of waste wood produced by municipal Park and Forestry Departments. Under the more stringent air pollution control criteria, which are either being advocated or already are in effect, the disposal of waste wood is becoming a critical problem. Certain conditions and circumstances prevailed in the City of St. Louis which emphasized the potential importance of this demonstration to many similar metropolitan areas. In summary, these conditions were as follows:

1. It was estimated that about 6,000 truckloads of waste wood (on the order of 6,000 to 10,000 tons) were generated each year by the Park and Forestry Departments of the City of St. Louis. Until this project was initiated, such waste wood was disposed of by open burning. However, current State and City regulations for the control of air pollution include provisions for the cessation of open burning, and it was necessary to provide another means of disposal of the waste wood. The same problem can be expected eventually in all major metropolitan areas.

2. It was estimated that about 1,000 truckloads (on the order of 2,000 tons) of waste bulky objects were produced each year by the population of the City of St. Louis. The existing incineration facilities of the City were not designed to accommodate such objects, and they were disposed of by burial. Sites for the burial of such materials are rapidly being exhausted. This problem already exists in all metropolitan areas.

3. The Department of Welfare of the City of St. Louis, which is responsible for administering the City Workhouse, was searching for ways whereby the Workhouse inmates could be provided with useful activity for purposes of prisoner rehabilitation. Among the activities deemed suitable for this purpose were the preparation of waste wood for sale as pulpwood, and the size reduction of bulky burnable objects to permit salvage or disposal by incineration in municipal facilities.

4. As an incidental but significant benefit of preparing waste wood for sale as pulpwood, it was considered that field operations of the Park and Forestry Departments could be made more efficient by virtue of less field labor being required in the handling of waste wood.

5. The use of Workhouse inmates for processing operations made it necessary to install the processing facilities on Workhouse grounds, since the inmates are required to remain on the grounds. However, the City Workhouse is located within about 2 miles of one of the City incinerators, with the two facilities directly connected by a major thoroughfare.

6. The project was intended to permit the gathering of data relating to the quantities and qualities of waste wood and bulky waste objects produced within a major City. Such data presently are virtually non-existent.

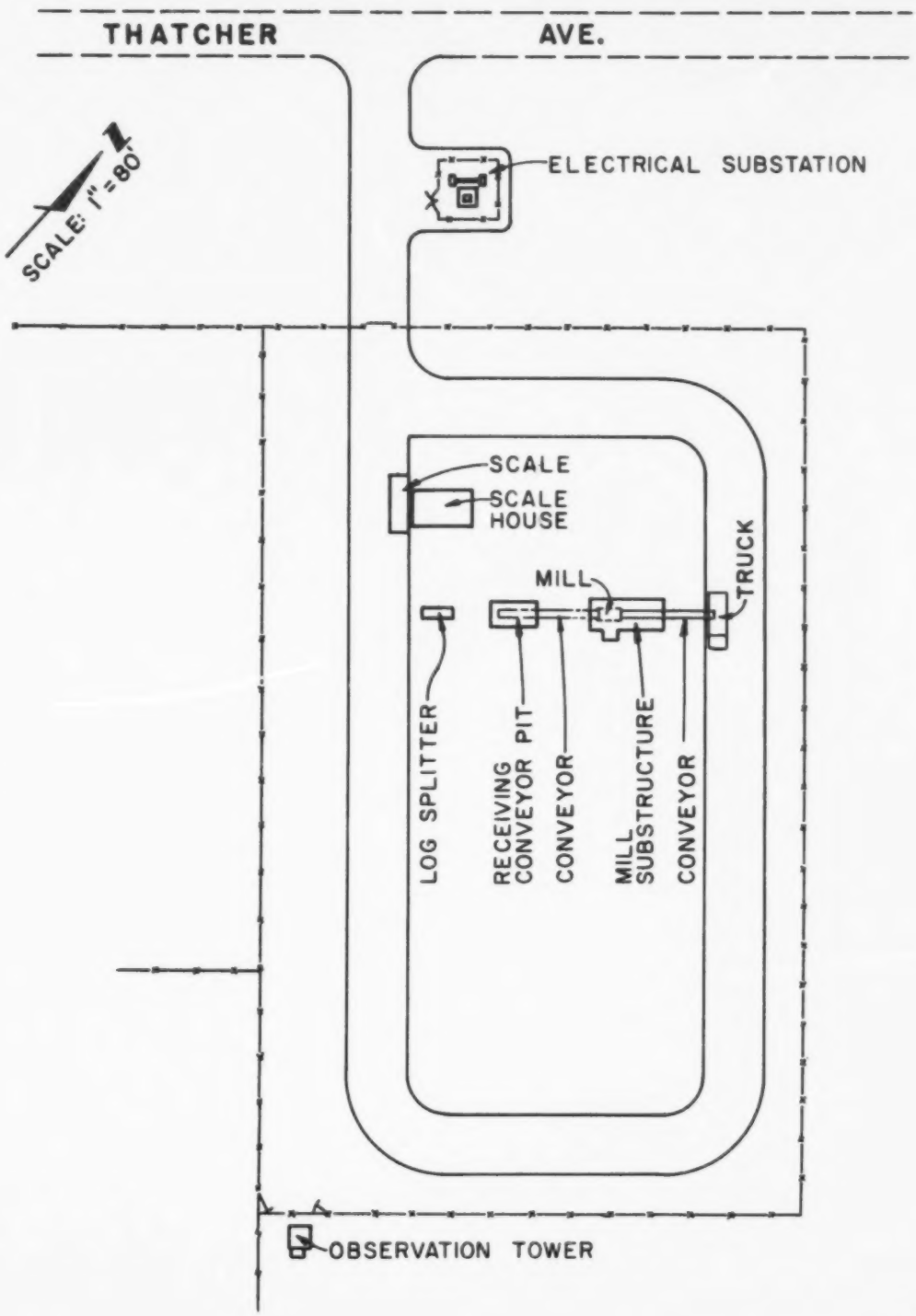
FACILITIES PROVIDED

An area of about 2.8 acres adjacent to the existing City of St. Louis Medium Security Institution (City Workhouse) was graded and fenced to provide space for processing logs and bulky refuse items and for the storage of both incoming and processed materials. Since most of the labor required for the handling and processing of waste materials was anticipated to be provided by inmates of the Institution, provisions for security were necessary in the design of the facilities. Further, since the project was intended to serve as a means of rehabilitation of the inmates, mechanization of the processing facilities was confined to those provisions deemed necessary for personnel safety, under the premise that there would be an abundance of manual labor available. Figure 1 shows a plot plan of the site.

The equipment installed for the project consists of the following:

1. A platform truck scale of 30 tons capacity with a 10-foot by 30-foot platform, and a dial type scale head. (See Figure 2.)

Figure 2 - Scale and Scalehouse



3A

PLOT PLAN
FACILITIES FOR PROCESSING WASTE WOOD AND BULKY REFUSE
CITY OF ST. LOUIS

FIGURE NO. 1

2. A log splitter, specified to be capable of splitting a 38-inch diameter log, 5 feet 6 inches long, into four segments, shown on Figure 3.

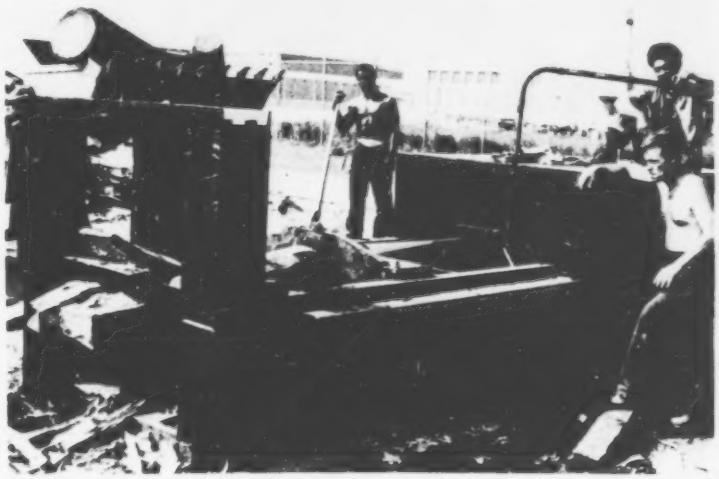


Figure 3 - Log Splitter

3. A horizontal hammermill, powered by an 800 horsepower, 900 rpm motor, with a feed opening approximately 48 by 60 inches, capable of reducing the items fed to it to particles no more than about 6 inches in their largest dimension, and capable of accepting the following:

   a. Household furniture, including upholstered sofas and chairs.

   b. Household refrigerators, up to approximately 7 x 4 x 3 feet in size, from which the motors and compressors have been removed.

   c. Household appliances, such as washers, dryers and stoves, from which the motors have been removed.

   d. Mattresses.

   e. Rubber tires. (Passenger car tires only.)

   f. Occasional metal items, such as bicycles, buggies and sheet metal yard furniture.

g. Tree branches and parts of tree trunks up to 8 inches in diameter by 5 feet long.

h. Demolition lumber of up to 2-inch planks, 10 feet long.

4. A feed hopper for the hammermill, equipped with an inlet curtain for containment of missiles and with an internal water spray for dust control.

5. A feed conveyor for the hammermill, consisting of a 60-inch wide steel slat type conveyor, with a horizontal loading section slightly above ground level, and with an inclined section (about 25 degrees from horizontal) to the inlet of the feed hopper.

6. An oscillating discharge conveyor, located below the discharge opening of the hammermill, about 48 inches wide and 10 feet 6 inches long.

7. A discharge sliding belt conveyor, to convey and elevate milled material from the oscillating conveyor to a height sufficient for discharge to trucks; equipped with a 30-inch wide rubber belt, sliding in a steel trough, traveling at a speed of about 120 feet per minute.

Figure 4 - Hammermill and Conveyors

The scale head, electrical control equipment and toilet facilities for personnel are located in a small concrete block building. In addition to the installed equipment, three small tractor loaders, adaptable for bucket loading or fork-lift operation, have been provided for transporting and handling the heavier logs and bulky items. One of these is used within the working area. The other two units have been provided for loading logs on Forestry Department trucks. Roll-off trucks and containers for transporting unmilled and milled materials also are provided.

METHOD OF OPERATION

The original concept of operation of the facilities was as tabulated in the following:

1. Each truckload of waste wood from forestry operations and of bulky refuse objects, such as construction debris, furniture and similar materials, would be weighed as the truck enters the processing area, with appropriate records kept of the weight, source, type of material, and other matters of interest.

2. The waste wood was to be sorted into the following categories:

   a. Wood salable with no further processing.

   b. Wood requiring cutting or splitting to become salable.

   c. Wood not suitable for sale, which would be cut or split as necessary and then shredded and incinerated.

3. Salable waste wood was to be processed and stored in piles for pick-up by a pulpwood dealer.

4. Bulky refuse items were to be processed through the hammermill.

5. All material leaving the processing area was to be weighed, with appropriate records kept of the type of material and its disposition.

Under the original concept, waste wood which would have been salable as pulpwood would have had to meet certain specifications. The wood would have had to be in uniform lengths of no more than 5 feet, with diameters no less than 3 inches and no more than 8 inches. All wood species except oak and hickory would have been acceptable. Larger logs would have had to be split to sizes less than 8 inches for acceptance. A local pulpwood dealer had indicated that a continuing market existed for such pulpwood.

As of June 1970, the pulpwood dealer was no longer operating in the manner previously anticipated. However, a privately owned and operated portable chipper became available for chipping logs at the Workhouse site

to provide a product suitable for sale. During part of the project operational period, this means was used for processing a portion of the waste wood. When the portable chipper was not available, the waste wood was either shredded and incinerated, or disposed of by sanitary landfill.

The market for scrap steel was depressed at the time the project was conceived, and no provisions originally were made for its recovery. In the meantime, the scrap market became more attractive. Some of the bulky refuse items, such as refrigerators and washing machines, with motors removed, were salable with no further processing.

The actual quantities of bulky refuse delivered to the processing facilities were far greater than the preliminary estimates. It is believed that this resulted from the initiation of several Federally funded inner-city clean-up programs, which had the effect of concentrating and increasing the volume of materials to be disposed of. Much of the material actually delivered as bulky refuse was comprised of materials which normally would be categorized as mixed municipal refuse, as usually collected in packer-type trucks. Such material was gathered in street and alley clean-up campaigns, and since it did contain some items which could be classified as bulky refuse, it was delivered to the bulky refuse processing facilities instead of to one of the City incinerators.

The revised procedures, as actually practiced, are as follows:

Procedure for Waste Wood

1. All waste wood delivered to the processing area was weighed, and appropriate data recorded.

2. The waste wood was dumped on the site in a temporary storage area.

3. The wood was sorted into the following categories:

   a. Pieces salable as pulpwood with no further processing required.

   b. Oversized pieces salable as pulpwood.

   c. Unsalable pieces less than 8 inches in diameter.

   d. Unsalable pieces over 8 inches in diameter.

4. Oversized salable pieces were cut and/or split in the splitter and returned to the pile of salable wood.

5. Some pieces salable as pulpwood were handled and processed in a privately owned and operated chipper, located on the site.

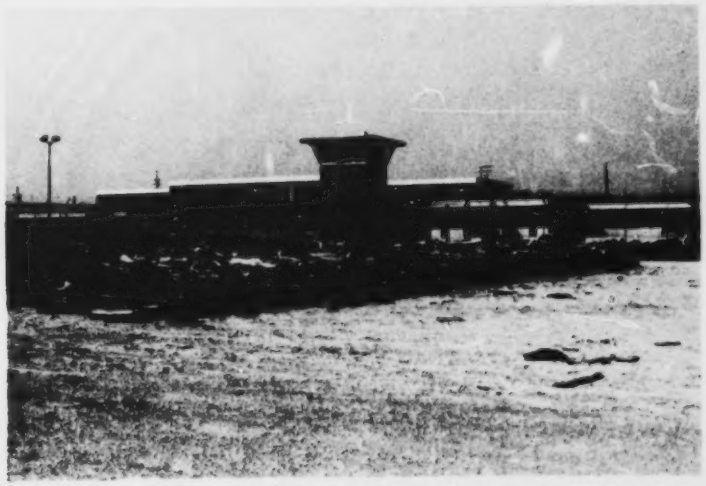


Figure 5 - Waste Wood Ready for Chipping

6. Some oversized unsalable wood was processed through the splitter, and then processed through the hammermill.

7. All unsalable wood, after being milled, was transported to either a sanitary landfill or a City incinerator.

8. Some oversized pieces were hauled directly to a sanitary landfill.

Procedure for Bulky Refuse Items

1. All loads of bulky refuse delivered to the processing area were weighed, and appropriate data recorded.

2. The bulky refuse was dumped on the site in a temporary storage area.

3. The bulky objects were sorted into the following categories:

   a. Objects to be shredded in the hammermill with no further processing.

   b. Objects such as refrigerators and washers which require motors and compressors to be removed before shredding.

   c. Objects which require special handling before disposal, such as water heater tanks.

4. Motors and compressors were removed from appliances and placed in containers for sale together with other salvable materials.

5. Items which could be sold for scrap without shredding were processed separately. For example, water heater tanks are salable, and their value enhanced by removal of casings and insulation. Similarly, the value of refrigerator bodies is enhanced by removal of liners and insulation.

Figure 6 - Refrigerator Bodies Ready for Sale to Scrap Dealer

6. All materials without salvage value were processed through the hammermill, except for those excess quantities which were hauled directly to a landfill.

7. All shredded material without salvage value was hauled either to a sanitary landfill or to an incinerator for final disposal.

OPERATING PERSONNEL

The project was administered under the Division of Refuse Collection and Disposal, Department of Streets, of the City of St. Louis. The operating personnel for the facilities, from the Department of Streets, were comprised of a supervisor (part time), a general maintenance man, two truck drivers, a construction equipment operator, and a records clerk.

The remainder of the labor required to operate the facilities was comprised of two guards and of inmates of the City of St. Louis Medium Security Institution. Between 28 and 37 of the inmates at one time were utilized in the processing operations.

Bulky refuse items were collected and delivered to the site by personnel of the Department of Streets. Waste wood was delivered to the site by personnel of the City of St. Louis Forestry Division. The Forestry Division performs Forestry operations on all City property within the City limits. Its field operations include the chipping of small branches with portable chippers, with the chips used for mulch in the City parks. Larger branches were cut into lengths about 5 feet long, loaded on trucks, and transported to the processing site.

Involvement of inmate labor in the operations created production problems. Although the Department of Streets has the responsibility for plant production, it had no direct control over inmate labor. The two guards furnished by the Medium Security Institution were primarily responsible for maintaining security and discipline, and in this case the achievement of high throughput rates was of secondary importance. Also of significance was the lack of incentive on the part of the inmates to work hard. The inmates were sentenced to the Institution for periods varying from 30 days to one year, and few of them showed any inclination to do any more than they were specifically instructed to do.

The deployment of personnel to the various functions performed at the project site is summarized in the following tabulation:

A. Wastewood Disposal Operation

1. Receive, weigh, and record incoming wastewood.

   a. Regular records clerk (Same as B, 1.a.)
   *b. Inmate records clerk (as required).

2. Separate incoming wastewood into three categories, large logs that are unable to be split, large logs which can be split, and small logs that can be processed without splitting.

   4 to 6 inmates

3. Split and stack separated, splittable logs.

   6 to 8 inmates

4. Load and haul logs that are unable to be split to landfill.

   a. Loader operator
   b. Truck driver (part time)

5. Processing acceptable wastewood into wood chips for sale to paper industry.

   a. Chipping machine operator (private operator)
   b. Truck driver (private operator)
   c. 8 to 10 inmates

6. Shredding wastewood

   a. Machine operator
   b. 6 to 8 inmates

7. Haul Shredded wastewood to incinerator

   Truck driver (part time)

B. Bulky Refuse Disposal Operation

1. Receive, weigh and record incoming bulky refuse

   a. Regular records clerk (See A-1-a)
   *b. Inmate records clerk (as required)

2. Removal of salvage metal from bulky refuse in storage

   Salvage metal dealer (private operator)

3. Feed bulky refuse on to shredder loading conveyor

   Loader operator

4. Monitor shredder feeding operation and remove items of bulky refuse which may be harmful to the machine.

   a. Machine operator
   b. 2 to 3 inmates

5. Monitor shredder discharge conveying system to ensure conveyor blockage does not occur at transfer point.

   1 inmate

6. Haul shredded bulky refuse to incinerator

   2 truck drivers (part time)

* One inmate is assigned to work as an understudy to the records clerk. This inmate works as the substitute for the records clerk, in event of absenteeism.

DISPOSITION OF BULKY REFUSE

The quantities of bulky refuse received and disposed of through the project facilities during the period from June 1, 1970 through March 31, 1972, are summarized in Table No. 1. During about two months preceding the initiation of plant operation, approximately 1,400 tons of bulky refuse were received and stored on the project site.

On several occasions during the project period, fires occurred in the piles of unprocessed bulky refuse. It is suspected that the fires were either of an incendiary origin, or were the result of carelessness on the part of the inmates. When fires occurred, they were brought under control and extinguished, usually with the assistance of the City Fire Department. The quantity of bulky refuse consumed in these fires is relatively insignificant when compared to the total quantity of material handled during the project operational period, and Table No. 1 does not reflect an allowance for the materials consumed in the fires.

Of the total quantity of 14,300.9 tons of bulky refuse received, 9,324.7 tons were milled and incinerated, 996.6 tons of metal were sold to salvage dealers, 40.4 tons of rubber tires were sold to salvage dealers, and 3,565.8 tons were diverted unprocessed to a sanitary landfill for disposal. The unanticipated quantity of bulky refuse received as a result of the inner-City clean-up campaigns made it necessary to utilize landfill for disposal, since the plant did not have the capability of processing all of the refuse received.

DISPOSITION OF WASTE WOOD

The quantities of waste wood received and disposed of at the processing plant are summarized in Table No. 2. About 650 tons of waste wood were delivered and stored at the project site prior to initiation of actual operations.

Of the 3,796.5 tons of wastewood received at the project site, 3,309.1 tons were stockpiled for chipping and 474.7 tons, or about 13 per cent, were hauled to a landfill for disposal. Of the wood stockpiled for chipping, only 815.8 tons, or 21 per cent, were actually chipped and sold, and 2,375.6 tons, or 66 per cent, were culled for milling and subsequent incineration.

Several circumstances prevailed which had an adverse effect upon the originally desired results of operation. The log splitter, used to split large logs into sections which could be either milled or chipped, proved to be inadequate to perform the desired function. The machine could not split the larger logs as was claimed in the manufacturer's literature, and it was impractical to mechanize the operation to achieve high production rates even for the smaller logs.

The private operator, who owned the portable chipper which processed a portion of the waste wood, did not operate consistently. From March 1971 through August 1971, no wood chips were sold. In September 1971, the chipping operation was resumed. However, the buyer complained that much of the waste wood, which had been stockpiled for months, was dry rotted, and was unsuitable for chipping. A more stable market for wood chips would have permitted greater productivity.

RECONCILIATION OF OPERATING TIME

Records relating to the actual hours of machine operation were maintained throughout the project demonstration period. Table No. 3 summarizes the records of possible operating time, actual operating time and time lost for the bulky refuse processing facilities. Table No. 4 summarizes similar data for the waste wood processing facilities.

During the first four months of operation, it was attempted to achieve 7 hours of operation per day, and this assumption is reflected in Tables 3 and 4. It soon became apparent, however, that as long as inmate labor was used, a 6-hour working day was as much as could be achieved. The 6-hour operating day is reflected in Tables 3 and 4 after the first 4 months of operation.

The lost operating time is categorized as that due to inclement weather, personnel problems and mechanical down time. The processing facilities are outdoors, and were not operated in rainy weather, or during periods of excessive cold or heat. The lost time attributed to personnel problems is that which resulted from the practices and security provisions required when using inmate labor. During the first 7 months of operation, considerable time was lost because of the unscheduled withdrawal of inmate labor to permit inmates to receive visitors. This condition was corrected by scheduling visits to inmates working on the project to Saturdays instead of throughout the week.

Additional lost time was caused by security provisions related to inmate labor. The initial procedure was to confine all inmates of the Medium Security Institution whenever disciplinary problems occurred anywhere in the Institution. This practice was changed by quartering those inmates working on the project in a separate section, thereby isolating them from the other inmates. After the first 7 months of operation, lost time attributable to personnel problems was almost eliminated.

Lost time due to mechanical problems was mainly due to equipment failures or to maintenance of more than a routine nature. The extremely severe service to which the equipment was applied was a principal reason for the relatively large amount of lost time in this category. The general lack of a feeling of responsibility on the part of the inmates operating the equipment also was contributory to greater maintenance and to more lost time.

EQUIPMENT PERFORMANCE

Waste Wood Process. There are essentially two pieces of equipment utilized in the waste wood process; the log splitter, which is part of the project's equipment, and the pulpwood chipping machine, which is the property of a pulpwood dealer who is using his machine to process City waste wood for chips.

The Hydraulic Log Splitter.

Description. The hydraulic log splitter is manufactured by the Carthage Machine Company, Inc., Carthage, New York. The machine consists basically of a large hydraulic ram having an 8-inch diameter cylinder which is rigidly attached to one end of a heavy steel frame. The ram has a piston stroke of 72 inches and is powered by a hydraulic pump capable of developing a pressure slightly in excess of 2,000 psi. The hydraulic pump is powered by a 25 HP 1,200 RPM, 3 phase electric motor. At the opposite end of the steel frame to which the hydraulic ram is attached, two heavy steel axes are mounted in a fixed position at right angles to each other. A hydraulic elevator, which is used to center the log to be split is positioned between the axe blades and the retracted position of the splitting ram.

Figure 7 - Hydraulic Log Splitter

Evaluation. Specifications for the hydraulic log splitter provided that the machine be capable of splitting logs 38 inches in diameter and 5 feet 6 inches long into four segments. The logs are split by the action of the hydraulic ram exerting pressure on the logs parallel to the grain, forcing them through the axe blades. The hydraulic ram will develop a splitting force in excess of 50 tons. It became apparent that even with a force of 50 tons, many clear, straight grained logs could not be split when they exceeded a diameter of 30 inches. Logs which had an irregular growth pattern and/or a large number of knots were often incapable of being split even when the diameter was as small as 18 to 20 inches.

White elm and sycamore species of wood comprise approximately 95 per cent of all the logs delivered to the plant. These varieties of wood are extremely difficult to split when compared with other types. Operation of the log splitter made it apparent that the manufacturer did not design it to accommodate large elm or sycamore logs. When the splitter is unable to completely split a log, the axe blades become embedded in the log and the log is extremely difficult to remove from the splitter. Removal of a log which has become lodged on the axe blades is a time-consuming task often involving the use of additional equipment and personnel. The ability to judge and select logs which the splitter can effectively split has become a necessary part of the log handling operation. Logs which are judged as unable to be split are disposed of by landfill.

In summary it may be said that the log splitter has not performed up to expectations, having considerably less capability than that required to effectively perform its function.

Maintenance. The log splitter is a relatively uncomplicated machine with slow-moving parts that require little maintenance. The following is a brief discussion of the type of maintenance which has been found to be necessary during the project period.

Lubrication. The hydraulic oil in the 150-gallon oil reservoir requires changing at 4 to 6 month periods. The manufacturer has recommended changing oil after 2,000 hours of operation. It has been found, however, that excessive amounts of water resulting from condensation in the oil tank necessitates a shorter oil change period.

The oil filter in the hydraulic system requires replacement at each oil change.

The ways which carry the splitting head and the grease fittings on the log elevator require lubrication on a daily basis.

Repairs. The splitter axes have broken away from their mountings on several occasions. Failure of the mountings has been caused by the severe service experienced in attempting to split the elm and sycamore species of wood. Repairs to the axes involved welding and building up of the mountings to provide additional strength. The splitter axes have been repaired on six different occasions.

Replacement of the leather oil cups on the piston head of the splitting ram was done on three occasions. Leaks which developed in the leather oil cups resulted in complete loss of splitting pressure. It appears that replacement of the oil cups will be required at least once each year.

The hydraulic control valves are operated by solenoid coils wired to the push button controls. The solenoids malfunctioned on two occasions requiring replacement.

Pulpwood Chipping Machine

Description. The City of St. Louis has an agreement with a private pulpwood dealer in which the dealer furnishes and maintains a trailer-mounted wood chipping machine at the waste wood disposal plant. The wood chipper will chip logs 9 inches in diameter, producing a cross grain wood chip approximately 1-1/2 inches wide by 1/4 inch in thickness. The wood chipper is powered

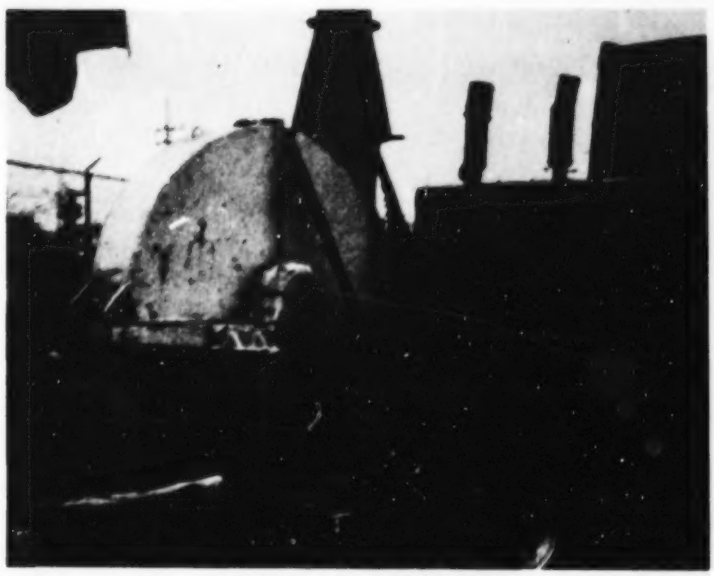


Figure 8 - Chipper

by a 6-cylinder diesel engine which is geared to turn the heavy cutting rotor at approximately 1,000 RPM. Production from the chipper ranges from 4 to 6 tons of chips per hour, depending upon the condition of the cutting blades. The wood chipper was made by the Budow Manufacturing Company, Warley, Georgia. Although the chipper is not part of the project equipment, the following comments are included as guidance for similar activities elsewhere.

Evaluation. The wood chipper is an old model machine which must be hand fed. However, the unit performs well considering its age. The major problem with the machine has been obtaining a chip product which is consistent in size. On occasion the machine will splinter off parts of logs which are too large to be accepted by the paper company. Installation of an oscillating screen separator by the pulpwood dealer provided a method of removing and recycling wood chips which were not of acceptable size. The 9-inch diameter limitation on log chipping capability is a considerable handicap. Approximately 60 per cent of all logs delivered to the processing plant require splitting to obtain the 9-inch diameter. The use of a larger chipper with the capability to handle 20-inch diameter logs would reduce the number of incoming logs requiring splitting to around 20 per cent.

Maintenance. The maintenance on a pulpwood chipper will vary considerably depending on the service conditions. The service that a wood chipper is subjected to when chipping municipal waste wood is far more severe than the service experienced in a normal wood harvesting operation.

Cutting Knives. Waste wood delivered for processing by the City Forestry Department often has been dead for some period of time and is quite hard as a result of seasoning. In addition to the waste wood being hard, foreign objects, such as nails and fence wire, are found embedded in the logs from time to time. The combination of wood hardness and occasional metal objects which have grown into the trees greatly increases maintenance to the cutting blades. The cutting blades which are currently in use require sharpening after an average of 64 tons of chip production.

Lubrication. The chipping machine and associated handling equipment requires lubrication on a daily basis. The lubrication process involves routine greasing of fittings and checking of oil levels in gear boxes and engines. Complete lubrication maintenance can be accomplished in approximately 30 minutes.

Non-Routine Recurring Maintenance. It was stated that the cutting blades on the chipper require sharpening after chipping

approximately 64 tons of chips. There have been occasions, however, when the damage to the cutting blades has been so great after chipping a log containing a piece of metal that complete blade replacement was required. There is no way to predict when such damage to the cutting blade may occur due to the nature and source of the wood fed to the machine. Severe damage to the chipping blades has occurred on approximately six different occasions during the project period.

Bulky Refuse Process. The bulky refuse milling equipment includes a loading conveyor, a hammermill type shredder, a discharge oscillating conveyor, and a discharge stacking conveyor. Each item of equipment is treated separately in the discussion that follows. The three conveyors in the system are manufactured by Maple City Stamping Company, Peoria, Illinois, and the hammermill is the product of Williams Patent Crusher and Pulverizer Co., Inc., St. Louis, Missouri.

Refuse Loading Conveyor.

Description. The loading conveyor is a steel belt piano-hinged type conveyor 60 inches wide and 48 feet long. The conveyor has a horizontal section 13 feet long at ground level

Figure 9 - Loading Conveyor in Foreground

and a section 35 feet long which is inclined at approximately 25 degrees from the horizontal. Stationary skirtboards 12 inches high are provided on each side of the conveyor. The conveyor moves at a speed of 45 feet per minute and has an apron made from 3/8-inch steel plate hinged to form flights with a 9-inch pitch. The conveyor is equipped with 4-inch metal cleats spaced at 4-foot intervals which serve to prevent material from sliding down the inclined metal apron. A heavy duty motor-reducer combination with a 15 horsepower capacity and a 100:1 ratio is used to power the conveyor. The drive train of the conveyor is equipped with a 70,000 inch-pound safety clutch for overload protection.

Evaluation. The conveyor has proven to be a rugged, durable machine, capable of performing the bulky refuse shredder loading operation. The loading conveyor experiences little difficulty in handling any form of bulky refuse. The conveyor is simple in design, making it relatively easy to perform necessary maintenance.

The conveyor is designed in such a manner as to require a 6-inch clearance between the hammermill charging hopper and the conveyor apron on the return side. The 6-inch opening is necessary in order to permit the steel cleats, welded to the conveyor apron, to clear the hopper. The problem created by this conveyor-hopper arrangement is one of housekeeping. Approximately 2 to 3 cubic yards of material per day is either hurled or blown through the opening by the fan action of the hammermill rotor. In addition to the fan action of the rotor, the steel cleats tend to drag material out of the hopper on their return. A substantial amount of the material carried back by the conveyor cleats is deposited at its lower end near the tail sprockets. This condition necessitates removal of the foundation cover plates and hand cleaning the pit on the order of twice a month. The cleaning process involves approximately 8 manhours of labor.

The safety clutch has posed problems due to its basic design which does not provide a satisfactory means of regulating the torque setting. The clutch is difficult to regulate and the resulting adjustment will invariably cause the torque to be either so great as to break the drive chain, or so low as to slip under normal loading. Continuous operation of the conveyor has been provided for by setting the clutch in such a manner as to allow no slippage. Protection of the drive train has been accomplished by installation of a current overload limiting switch on the conveyor drive motor. The current limiting device is set to permit the conveyor motor to draw only that amount of current that is necessary to drive the conveyor and its normal load. When overloading or blockage occurs on the conveyor, the line current will surge above the setting, tripping the limit switch, and thereby stopping the conveyor.

Refuse Loading Conveyor Maintenance. The loading conveyor requires a relatively small amount of maintenance. Normal lubrication once per week provides sufficient protection to the bearings.

The conveyor has been in regular operation for 22 months and is beginning to exhibit considerable amounts of wear to the rollers of the apron chain and to the conveyor flights. The large amount of wear is attributed to the highly abrasive dust and grit found to be present in bulky refuse when it is delivered to the plant. At current rate of wear, the worn elements of the conveyor will need replacement in approximately two years.

Shredder.

Description. Size reduction of bulky refuse is accomplished by a Williams Model 560 shredder. The shredder is equipped with a horizontal rotor having 22 - 130-pound swing-type hammers. Combined weight of the rotor and hammers is slightly in excess of 20,000 pounds. The rotor is housed in a crushing chamber fitted with 2-inch thick breaker plates and lined on the sides and top with replaceable carbon manganese steel liner plates. Manganese

Figure 10 - Shredder and Motor

steel cage bars, with 6-inch by 13-inch openings, form the lower portion of the chamber. Particle sizes as discharged from the chamber are approximately 6 inches in their largest dimension. The feed opening of the shredder is 50-1/2 by 63 inches. The working face of the rotor is 50 inches in length and the swing hammers form a circle 60 inches in diameter when the rotor is turning at normal speed. The shredder is powered by an 800 horsepower, direct-connected, 3 phase, induction-type electric motor which turns at 900 RPM.

Evaluation.

Positive Operational Features. Operation of the shredder during the project period has demonstrated that the machine meets the functional design criteria as specified. The shredder is capable of milling the types of bulky refuse as specified with minimal operating problems. It must be emphasized, however, that rigid control must be maintained while feeding the shredder, to ensure that no dense metal objects will inadvertently enter the machine and cause damage. The average milling rate of the shredder is on the order of 10 tons of bulky refuse per hour with a maximum production rate of 21 tons per hour.

Negative Operational Features.

Damage Prone. The use of a shredder to effect size reduction on bulky refuse subjects the machine to operating conditions which can result in serious internal

Figure 11 - Typical Mixed Bulky Refuse

damage. Bulky refuse is extremely heterogeneous, consisting of many different kinds, shapes and sizes of materials. The general appearance of bulky refuse after it has gone through the collection, hauling, unloading, and stacking processes is often that of a hopelessly entangled mass of nearly every type of solid waste.

This heterogeneous mixture of material has proven to be difficult to handle and control. At the inception of the project an attempt was made to use hand labor, furnished by institution inmates, to feed the loading conveyor. The use of hand labor appeared to be a positive means of separating objects from the bulky refuse which could cause internal damage to the shredder. Feeding of the loading conveyor with hand labor proved to be extremely slow and at times even impossible, since massive entanglements of bulky refuse would occur, rendering the use of hand labor relatively ineffective as a means of materials handling. Experience in attempting to handle the bulky refuse by hand soon established that the most reasonable solution was to use a front-end loader to handle the material. The use of a front-end loader to feed the shredder creates conditions which make it difficult to detect and remove all items which may cause damage to the shredder. The shredder rotor has sustained damage on one occasion when a short piece of 10-inch "I" beam went through the machine. On another occasion, three cracked cage bars were detected and required replacement when an unidentified piece of dense metal was noticed after being discharged from the shredder. On other occasions such items as 5-inch artillery projectiles and hand grenades passed through the shredder. Such materials can very easily lead to serious equipment damage and extended periods of machine downtime.

Stalling. Shredders can and will stall under certain loading conditions. Surge loading of the mill is an inherent problem which occurs in handling bulky refuse. Several factors which contribute to this condition are: batch feeding by front-end loader, entangled masses of materials which are almost inseparable, and the tendency of material to roll down the feeding conveyor incline and bunch up before eventually entering the shredder. When surge loading occurs and there is a significant amount of dense material present, or if the load includes such items as rugs, bed springs and inner-spring mattresses, the shredder is likely to stall. When stalling occurs,

the fuses blow in the power line to the electric motor, and the shredder rotor grinds to a halt, usually becoming locked in position. Before the shredder can be restarted, all debris must be removed from the hopper and the rotor must be cleared. Clearing the rotor often involves removing the cover and pulling the cage bars to permit the blockage to drop out the bottom of the crushing chamber.

Winter Operation. Operation of the shredder in its outdoor location, at temperatures below 25 degrees F., presents several problems. Moisture on the rotor tends to freeze as the shredder stands idle overnight. The freezing action tends to form ice lenses between the rotor ends and the shredder housing, which are in close proximity to each other. When such freezing occurs, the rotor is locked in place and cannot be moved until heat is applied to melt the binding ice lenses.

The most serious problem caused by low temperature occurs as a result of the necessity to operate the shredder with the feed hopper sprinkler system turned on. The sprinkler system is needed to help control dust and to quench and cool pieces of metal from the bulky refuse which are hot enough to ignite the combustible materials which have been shredded. Attempts to operate the shredder without sprinkler water have resulted in fires in the shredded material in the trucks en route to the disposal point. In addition, if sufficient water is present, the shredded material will freeze in the trucks, making it impossible to dump the material at the disposal point.

Dust Control. Considerable amounts of dust and small particles of paper and fiber are discharged from the hopper during the shredding process. This condition is a particular problem during dry seasons of the year. The application of water by means of a sprinkler system in the hopper helps to minimize the dust problem. However, when incineration is used as the means of ultimate disposal, excessive water creates problems in attempting to burn the material.

Shredder Maintenance. Routine recurring maintenance to the shredder consists of retipping worn hammers, changing the lubrication oil, replacing missile deflector curtains, and securing bolts on the shredder housing which become loose due to intense vibration.

Retipping Worn Hammers. The shredder hammers normally require retipping after grinding approximately 1,000 tons of bulky refuse. Hammer retipping is usually done on Saturdays in order to prevent downtime from occurring during the work week. The retipping process is accomplished by using two types of welding rod; a build-up rod and a hard surface rod. The build-up rod is used to bring the hammer back to its approximate original shape, and the working faces of the hammers are overlaid with a 3/16-inch thick hard surfacing material. Various types of welding rods were used during the project. It was noted that nearly all suppliers of welding materials could furnish a product that would meet the general requirements, thus allowing competitive bidding for the welding rod. The City is currently informing suppliers to furnish welding rod which will meet the following description:

Build-Up Rod. The build-up rod shall be 1/4-inch diameter, tough and ductile, alloyed to work-harden under heavy impact resulting in good abrasion resistance equivalent to manganese. The build-up rod shall produce the following physical properties in the weld deposit:

Brinell Hardness	As Deposited	190-210
Brinell Hardness	As Work-Hardened	500-600
Tensile Strength	120,000 + 10,000	psi
Yield Strength	75,000 + 10,000	psi

Hard Surface Rod. The hard surface rod shall be 5/32-inch in diameter and designed to be used as hard facing on either mild or manganese steel. The weld deposit shall possess wear qualities which are highly resistant to heavy impact and severe abrasion. The rod shall produce a weld having a Brinell hardness as deposited of 500 to 600.

The average cost of retipping hammers after having shredded 1,000 tons of bulky refuse was found to be $256.00, or $0.26 per ton. The cost breakdown for hammer retipping per 1,000 tons for the Williams shredder, excluding electricity, amounts to $202 labor, $35 for build-up rod, and $19 for hard surface rod. Inmate labor was used in removing and replacing the shredder cover resulting in a small reduction in labor cost for the retipping operation.

Lubrication. The lubricating oil must be sampled periodically in order to check quality. Water deposits caused by condensation in the oil reservoir tend to develop

in the lubrication system, and the oil requires changing approximately every six months as a result of the condensation problem.

Replacement of Missile Deflector Curtains. Two rows of heavy rubber belting are draped in the upper section of the shredder feed hopper. The belting serves to prevent missiles from being hurled from the hopper during the shredding operation. The belting forming the inner curtain is bombarded continuously by jagged pieces of shredded metal. The inner deflector curtain must be replaced after approximately 200 hours of shredding time, as a result of the severe punishment sustained from the missiles. Failure to replace the deflector curtains when they become worn results in a hazardous operating condition.

Securing Shredder Bolts. The impact of the shredder hammers on bulky refuse as it is being ground produces intense shock vibrations in the machine. The vibrations serve to loosen virtually every bolt on the shredder from time to time. Many bolts must be tightened daily.

Replacement of Loading Conveyor Sprocket Guards. Two metal guards are located in the shredder hopper where the loading conveyor enters the hopper. The guards are made of 3/8-inch steel plate and serve to prevent debris from becoming entangled in the loading conveyor head sprockets. The metal guards are continuously bombarded by flying missiles during the shredding operation and must be replaced after approximately 6 months of service.

Nonroutine Maintenance performed on the shredder consists of major repairs which have been required as a result of damage sustained by the machine during operation. This type of maintenance has been by far the most costly, both from the standpoint of expenditures and the amount of downtime experienced.

Rotor Repairs. The center discs on the rotor cracked on two different occasions. Two months after the shredder was initially placed in operation, a 2-inch thick manganese steel liner plate worked loose from its mounting and dropped into the path of the rotating hammers, cracking three center discs on the rotor, and damaging the rotor cover. The removal of both the rotor cover and rotor was required in order to effect repairs. The cost of repairing the damaged cover and rotor amounted to $7,286.52 and resulted in two months downtime. Six months after the shredder was placed back in operation, another cracked center disc was discovered on the rotor. The damage to the center disc plate is

believed to have been caused by a short section of 10-inch I-beam which entered the shredder undetected. In this case the cracked disc was welded in place, resulting in a cost of $340 and four days downtime.

Replacement of Damaged Cage Bars. The lower portion of the crushing chamber is formed by seven heavy steel cage bars. In November 1971, a piece of dense metal passed through the shredder cracking three cage bars. Replacement of the cage bars cost $687 and resulted in three days downtime.

Shredder Drive Motor.

Description. The shredder drive motor is an 800 HP, 4,000 volt, 900 RPM, squirrel-cage, induction machine manufactured by Allis Chalmers, Inc. The motor is direct-connected to the hammermill, and is designed to accommodate high inertia and wide, sudden load variations. The motor is totally enclosed, separately ventilated, and designed for operation out-of-doors in a dusty area.

Evaluation.

Positive Operational Features. The shredder drive motor has functioned satisfactorily during the project period. The operating conditions varied widely, exposing the motor to extreme conditions involving dust, moisture, heat, cold and heavy loading. Periodic resistance tests of the motor windings indicate that the motor has remained functionally sound despite the severe operating conditions.

Negative Operational Features. The bearings on the motor shaft are enclosed in a split housing. The bolts securing the upper half of the bearing housing work loose occasionally and must be frequently checked and tightened.

Maintenance. During periods in which the operation is particularly dusty, the motor air filters must be cleaned at least once each week. Cleaning air filters adequately will often require as much as 2 manhours, depending on how dirty the filters may be.

Water pockets, caused by condensation, tend to form in the oil pots which contain the bearing lubricating oil.

Discharge Oscillating Conveyor.

Description. The discharge oscillating conveyor receives the shredded bulky refuse from the discharge of the shredder and transfers the shredded material to a belt conveyor. The pan of the

discharge oscillating conveyor is fabricated from 1/2 inch thick steel plate with a maximum depth of 30 inches, 4 feet wide and 12 feet in length. The bed of the conveyor is sloped downward on an angle of about 8 degrees from horizontal toward the discharge end. The discharge oscillating conveyor is driven by an electric motor through a positive eccentric shaft drive with a one-inch stroke. The motor is a 7-1/2 horsepower, 460 volt, 3 phase, 60 cycle unit with V-belt drive. The conveyor is a product of Maple City Stamping Company, Peoria, Illinois.

Evaluation. The discharge oscillating conveyor has performed satisfactorily in all respects during the project period.

Discharge Oscillating Conveyor Maintenance. Routine reoccurring maintenance to the oscillating conveyor has consisted of weekly lubrication and periodic tightening and replacement of V-belts.

In October 1971, the City Fire Department was called in to extinguish a fire in the bulky refuse storage area. During the process of putting out the fire, the pit in which the oscillating conveyor is installed was flooded, submerging the conveyor drive motor. As a result, it was necessary to replace the bearings and dry the windings of the conveyor drive motor.

In February of 1972, a bearing was replaced on the eccentric shaft of the oscillating conveyor as a result of improper lubrication.

Discharge Belt Conveyor.

Description. The discharge belt conveyor receives the shredded material from the discharge oscillating conveyor and transfers it to the haul units. The conveyor is 30 inches wide by 47-1/2 feet in length, moves at a rate of 110 feet per minute and is inclined at an angle of 30 degrees to the horizontal. The conveyor belt slides in a steel trough with 10-inch skirt boards flaring out from the belts 30-inch width at the bottom to a width of 39 inches on top. The conveyor is driven by a 7-1/2 horsepower, 460 volt, 3 phase, 60 cycle, electric motor through a 100:1 Falk 600 AUD speed reducer.

Evaluation.

Positive Operational Features. The discharge belt conveyor is of sturdy design capable of withstanding heavy loading conditions without difficulty. Fabrication of the conveyor has been such as to allow easy access to all areas for inspection and maintenance. The component parts of the conveyor are stock items locally available, making it easy to obtain replacement parts.

Negative Operational Features. Although the sliding belt conveyor is adequate as a means of transferring shredded bulky refuse, certain installation features could be improved.

Figure 12 - Discharge Conveyor

Problems are constantly experienced at the transfer point from the oscillatory conveyor to the sliding belt conveyor. This transfer point has a restriction because the oscillating conveyor is wider than the sliding belt conveyor. The shredded bulky refuse is an extremely variable type of material, ranging from fluffy fibrous particles to a dense aggregate of granular materials and shredded metal. The shredded bulky refuse tends to roll on the belt of the conveyor, piling up at the transfer point. It is necessary to station a man with a prod pole at the transfer point in order that he may assist the material up the conveyor incline. The manpower used for this task is inmate labor and consequently is not a cost item. If inmate labor were not available, the conveyor design would have to be changed to properly accommodate transfer of the shredded refuse. A more satisfactory design probably would incorporate

a troughing belt, with greater width and less slope, and a belt speed of about 200 feet per minute, with no constriction at the transfer point.

The area around the tail pulley of the sliding belt conveyor must be cleaned twice daily when the plant is in normal operation. The use of the sprinkler system to quench the hot particles of shredded metal and keep the dust down when the shredder is in operation, tends to wash large quantities of fines down the conveyor causing piling at the tail pulley. The fines accumulating at the tail pulley will cause the belt conveyor to jam and will also plug the floor drain located a few feet away, if they are not cleaned up regularly.

Discharge Belt Conveyor Maintenance.

Routine Reoccurring Maintenance.

Lubrication. The return rollers on the conveyor require greasing once each week. The oil level in the gear reducer requires checking once each month with an oil change in the reducer once each year.

Clearing and Adjustment of the Tail Pulley. The tail pulley requires clearing on the order of once each week. Wire from shredded bed springs tends to get caught on the pulley and wind around the supporting shaft. A cutting torch is used to accomplish the wire-clearing process. The take-up screws on the tail pulley must be monitored continually and adjusted three to four times each week to maintain proper belt alignment and tension.

Nonroutine Maintenance. The belt conveyor has elongated approximately 3 feet since beginning operations. Elongation of the belt has required cutting, removal of a section of belt and resplicing twice during the project period. The belt currently is showing evidence of considerable wear and requires replacement. It is believed that the sliding belt will require more frequent replacement than would a troughing belt.

Loading Equipment. During the project period several types of loading and hauling equipment were used. Part of the original concept of plant operation was to use inmate labor to feed bulky refuse into the shredder manually. In the first two weeks of operation it was determined that with the heterogeneous mixture of bulky refuse actually received at the project site, the manual method of feeding the shredder was unacceptable. It became apparent that some type of loading equipment would be required to accomplish the shredder feeding operation. The

use of manual labor to feed the shredder resulted in a very low production rate. The bulky refuse proved to be extremely difficult, if not nearly impossible, to handle in this manner. A rubber-tired tractor, a crane with a clam shell bucket and a crawler-type front end loader were used at various times for raw materials handling during the project.

Tractor Loader with Rubber Tires.

Description. The first type of loading equipment to be used in feeding the shredder was a Case 580 industrial type tractor. The Case 580 machine was purchased as part of the original project equipment and was to be used in towing log wagons and maintaining the yard area. The tractor loader came equipped with a 3/4 cubic yard bucket, wheel weights and pneumatic tires.

Evaluation. The Case 580 loader increased production substantially, but the machine proved to be much too small to do an adequate job. The pneumatic tires proved to be a constant problem with much lost time occurring due to flat tires. Since the original table of organization did not provide for an equipment operator, the tractor loader was operated throughout the project by inmates of the institution. The inmates in general lack experience in machine operation and showed no inclination to practice any form of normal machine care. Despite instructions to the contrary, the inmates subjected the tractor to extreme abuse when they operated it. The tractor has been in service for 22 months, but has the appearance of having been operated 10 years under severe conditions. Considering the operating conditions to which this machine has been subjected, it can be stated that the tractor has performed reasonably well.

Maintenance. In addition to the normal routine maintenance required by the Case 580 tractor, a considerable amount of maintenance was required on the pneumatic tires. During the first 6 months of operation one complete set of pneumatic tires was worn out and $690 in tire repair service charges had been accumulated. As a result of the problems experienced with pneumatic tires, a decision was made to equip the machine with solid tires. The solid tires are made of radially laminated rubber and fiber material, and the drive wheels were provided with vulcanized road grader type lugs to promote traction. The total cost of equipping the tractor with these tires was $2,375 for four wheels. The solid tires have provided excellent service and have eliminated vehicle downtime due to tire maintenance.

The arms of the frame supporting the bucket on the tractor were broken on three different occasions. This problem was resolved by strengthening the bucket arms to permit them to withstand the loading conditions.

Koehring 605 Crane. During August and September of 1970, the shredder was down for rotor repairs. Bulky refuse brought to the plant during this period accumulated into a backlog of 1,760.94 tons before the shredder was placed back in operation. Plant operation in the month of October 1970 indicated that much greater production would have to be achieved in order to dispose of the backlog of bulky refuse in storage. In order to increase production, additional loading equipment was needed to feed the shredder. A departmental inquiry disclosed that the only piece of available equipment at the time was a Koehring 605 crane, equipped with a clamshell bucket. Arrangements were made to borrow the crane and the necessary operating personnel for use until the backlog of stored bulky refuse was disposed of.

Description. The Koehring 605 crane, which weighs 104,900 pounds, is equipped with a 60-foot boom and 1-1/2 cubic yard clamshell bucket. The machine is extremely powerful but is slow-moving and awkward. The crane is mounted on a high gantry A frame with 158-inch x 110-inch crawler tracks having 36-inch wide shoes. The crane has a maximum working radius of 55 feet and is capable of stacking material to heights of 40 feet.

Evaluation. The Koehring crane proved to be useful piece of equipment when used to stack bulky refuse for storage and to feed the shredder conveyor. Although the crane provided a means of easily handling bulky refuse, it possessed many disadvantages because of its size. The crane clamshell bucket was difficult to control when feeding the shredder. Overloading of the conveyor occurred from time to time when the crane operator would misjudge the quantity of material he had placed on the conveyor. On two different occasions the crane bucket struck the loading conveyor, causing minor damage. The crane was unable to completely clean the ground where refuse was stacked, leaving approximately 2 feet of debris which had to be picked up with a front end loader. The greatest disadvantage in using the crane was that it required two operators to run it, thus incurring additional personnel cost. In general the crane proved to be a very effective machine for moving large quantities of refuse, but the machine was too large to be considered appropriate for full time use in a small plant.

Maintenance. During the short period of time the crane was in use at the plant, it proved to be a very low maintenance machine. The machine required little more maintenance than routine lubrication and servicing. The primary reason attributed to the low maintenance requirements was that the machine was greatly oversized for the type of work it had to perform.

Track Type Loader.

Description. In March 1971, a track type loader became available for use on a temporary basis. This machine is normally used in the City incinerator plants as back-up equipment in the event of breakdowns. The loader was an HD11G Allis Chalmers with a 2-1/4-yard bucket.

Evaluation. The track loader has thus far proven to be the best suited machine to accomplish the bulky material handling operation. The versatility, maneuverability and capacity of the machine permits it to accomplish all the loading, stacking and clean-up operations which are required at the plant. After having used the track loader for a period of time, a decision was made to purchase such a machine to be used on a permanent basis. The machine, which is currently performing the loading operation at the plant, is a Case 1150 with a 2 cubic yard bucket. Although this machine is somewhat smaller than the Allis Chalmers HD11G, it is performing well, in all respects.

Maintenance. A track type loader requires a qualified operator who is responsible for performing daily preventive measures on the machine. Daily preventive maintenance usually requires approximately 30 minutes. More extensive servicing is required at scheduled maintenance intervals, such as clutch adjustments, filter changes, oil changes, etc. Daily operation of a track-type front-end loader in an environment such as at the bulky refuse plant, will involve track replacement on the order of once every three years. Track-type front end loaders require knowledgeable and conscientious operators to prevent excessive maintenance.

Hauling Equipment. The two types of hauling units which were used during the project demonstration period included 14 cubic yard dump trucks, and 40 cubic yard roll-off container trucks. The 40 cubic yard roll-off container trucks were purchased to be used as project equipment. However, delivery had not yet been made at the time the plant was ready to begin operation, and, in order to allow plant operation to proceed, dump trucks from the City incinerator were used as haul units at the plant during the first three months.

Description. The dump trucks are tandem axle, 37,000-pound gross-vehicle-weight units, with 14 cubic yard dump beds. The roll-off container trucks are tandem-axle 54,000 gross-vehicle-weight units, equipped with 40 cubic yard roll-off type containers, which form the loading bed of the truck when mounted. Both the 14 cubic yard dump trucks and the 40 cubic yard container trucks are products of the International Harvester Company.

Evaluation. The 14 cubic yard dump trucks were too small to carry a sufficient pay load. The loads hauled by these units averaged 9,200

pounds. The round trip travel to the dumping point and back requires 30 minutes. The refuse shredder is able to load a 14 cubic yard truck in approximately 16 minutes, and consequently three 14-cubic yard units were required to keep the shredder in continuous operation.

The 40 cubic yard roll-off container trucks proved to be the units best suited for the hauling operation. The refuse shredder is capable of loading the 40 cubic yard roll-off containers in approximately 30 minutes. With a 30-minute loading and 30-minute hauling cycle, two such units can keep the shredder operating at optimum capacity. The one major difficulty associated with hauling milled bulky refuse in the 40 cubic yard units occurs when the container truck driver allows the unit to become overloaded. When overloading occurs, the truck is usually carrying a load in excess of 25,000 pounds with the center of gravity of the load toward the front of the truck. Such a load distribution will cause the truck hydraulic system to fail and the dumping operation then cannot be accomplished in the normal manner.

It has been found that the roll-off feature, which allows containers to be located at any desirable location, is extremely practical and beneficial. The City is currently using six containers with the two available haul units. The containers which are not in use at the refuse shredding plant, are positioned at the City incinerators. City residents who wish to dispose of bulky refuse are permitted to place the material in the containers after properly identifying themselves as property owners. The system has worked so well that in 1971 a total of 2,808 tons of bulky refuse has been disposed of through this system with no direct collection cost to the taxpayer.

Maintenance. In addition to normal routine maintenance, the container haul units have required maintenance work to the hoisting units and the container tipping frame. The hoisting units require the use of approximately 50 feet of cable to winch the containers up and on to the container tipping frame. The hoisting cables require replacement approximately every three to four months of service. The container tipping frame is hinged at the rear of the truck frame, and has two hydraulic cylinders mounted in such a manner as to cause the tipping frame to move up and down by actuating a hydraulic control valve. The tipping frame can be damaged very easily by the truck operator during the loading and unloading operation. The driver must take care to be perfectly aligned with the container before attempting to load it. If the container is loaded too heavily, the cable hoist and tipping frame are subjected to a loading condition which can easily cause damage to either one or both. If the container is not resting on fairly level ground when loading is attempted, the container runners will engage the tipping frame unevenly and cause twisting of the container and the tipping frame. Such conditions, as discussed above, have led to damage and subsequent repairs to container truck tipping frames on eight occasions.

PROJECT COST SUMMARY

The actual capital and operating costs of the subject project are not translatable directly for comparison with similar projects in other communities. Substantial portions of both capital and operating costs were borne by the Environmental Protection Agency, because of the nature of the project as a demonstration. Much of the labor utilized for operation was that provided by prisoners of the City's Medium Security Institution, instead of by paid employees. As a consequence, the actual labor costs do not reflect the total amount of labor utilized. Further, the low productivity of the prisoners distorts the actual labor requirements for a project of this type. The following discussion of capital and operating costs reflects those adjustments made to allow the costs to be applied to other communities.

Capital Costs. The total capital cost of the project was $414,720.13. Two-thirds of this cost ($276,480.09) was funded by the Environmental Protection Agency. The remaining $138,240.04 was funded by the City of St. Louis, with $103,500 from part of a general obligation bond issue, and the remainder ($34,740.04) from general City revenue. This funding arrangement obviously cannot be counted upon for a similar project in another community.

For purposes of comparison, a more realistic method of funding capital cost would be by the issuance of municipal bonds. Such bonds often are issued for a 20-year term, and in this case, with an assumed interest rate of 4.0 per cent per year. It is further assumed that the initial capital cost would include rolling stock. The average annual debt service for this project then would be about $30,523. Based upon the actual quantity of bulky refuse (9,324 tons) and waste wood (2,376 tons) processed through this equipment, the unit amortization cost would be about $4.78 per ton of material processed over the 22-month period of operation.

Of the total capital cost, it is estimated that about $82,156 is assignable to waste wood disposal, and the balance, about $332,564, assignable to bulky refuse disposal. This allocation of cost must be regarded as only an approximation, since portions of the equipment and facilities were utilized for both waste wood and bulky refuse. The estimated unit amortization cost for the disposal of 2,376 tons of waste wood, therefore, is about $4.62 per ton and that assignable to the disposal of 9,324 tons of bulky refuse about $4.82 per ton, again over the 22-month operating period of the project.

Operation and Maintenance Costs. The original project included the following personnel:

General Maintenance Man	1
Security Guards	2
Typist Clerk	1
Heavy Equipment Operator	1

As the project progressed, it became evident that the unanticipated increase in material to be processed made it necessary to provide additional specialized personnel as follows:

Heavy Equipment Operator	1
Construction Equipment Operator	1

The Construction Equipment Operator was hired to operate the track-type front-end loader which was purchased to load and handle bulky refuse. The second Heavy Equipment Operator was hired to operate the second bulky refuse haul unit which was necessary to handle the increased volume of material. The actual operating personnel costs assignable to the project, including administration, therefore are as follows:

Personnel Costs - Original Project Paid from Project Funds	$64,462.10
Additional Personnel Costs Not Paid from Project Funds	15,572.50
Total Personnel Costs	$80,034.60
Less - Personnel Costs Assignable to Maintenance	3,519.79
Assignable to Bulky Refuse Processing	63,084.81
Assignable to Waste Wood Processing	13,430.00

Maintenance costs for the 22-month project period are summarized in the following tabulation:

Item	Labor	Parts and Supplies	Total
Shredder	$5,127.50	$12,229.91	$17,357.41 *
Conveying Equipment	1,280.00	4,286.93	5,566.93
Log Splitter	842.50	1,193.97	2,036.47
Loading Equipment	2,095.50	6,468.05	8,563.55
Hauling Equipment	1,176.31	5,905.57	7,081.88
Yard and Facilities	808.00	1,801.48	2,609.48
Miscellaneous	-	1,115.19	1,115.19
Subtotal Labor	11,329.81 **		
Total	$ 7,810.02	$33,001.10	$40,811.12

* Does not include $3,643.26 absorbed by shredder manufacturer for rotor repairs, September 1970.

** Includes maintenance labor cost ($3,519.79) of project personnel (General Maintenance Man) already reflected in the personnel cost section.

For purposes of this report, it is considered that only those maintenance costs relating to the log splitter are assignable to the processing of waste wood. Thus, the maintenance labor cost would be $842.50, with parts and supplies amounting to $1,193.97. The remainder of the listed maintenance costs thus would be assignable to bulky refuse processing.

Waste wood processing is considered to include the sorting procedures and the splitting operations. A portion of the waste wood, after splitting, was milled and delivered to the incinerator for disposal. This portion is included as part of the bulky refuse processed.

The only utility cost which has been charged to the project is that relating to electric power and sub-station rental. For the project period this cost has totaled $8,300.51. Since essentially all of the power consumed by the project equipment was attributable to the shredding operation, the entire power cost was assigned to bulky refuse disposal. No water cost has been charged to the project, since City facilities are not billed by the City Water Department. The cost of sewerage services also is not billed to the project, since the Metropolitan St. Louis Sewer District, a separate agency, bills the City on a lump sum basis, and individual City facilities are not identified.

Revenue from Recovered Materials. During the project period some revenue was derived from the sale of materials. Revenue from the sale of wood chips amounted to $2,486.17. Revenue from salvaged metal totaled $2,398.24, and from salvaged tires, $215.81.

Incineration Costs. Combustible materials, including bulky refuse and waste wood, which have been processed through the hammermill, are hauled a distance of about two miles to one of the City's incinerators for final disposal. The estimated unit cost of the incinerator operations, including amortization, is $4.75 per ton. This cost is included in the following summaries of processing and disposal costs for bulky refuse and waste wood.

Unit Cost of Processing and Disposal of Bulky Refuse. The estimated unit cost of bulky refuse disposal include those costs attributable to a portion of the waste wood which, although processed through the log splitter, was eventually milled and incinerated. The unit costs over the 22-month project period may be summarized as follows:

Bulky Waste Processed and Incinerated	9,324 tons
Waste Wood Processed and Incinerated	2,376 tons
Total	11,700 tons

Operation and Maintenance Costs

Operating Personnel	$ 63,084.81
Maintenance Labor	10,487.31
Parts and Supplies	31,807.13
Utilities	8,300.51
Total Operation and Maintenance Cost	$113,679.76
Amortization Cost (Est.)	$ 30,523.00
Incineration Costs Assignable to Bulky Waste	$ 55,575.00
Total 22-Month Project Cost	$199,777.26

Unit Costs

Operation and Maintenance	$ 9.72 per ton
Amortization (Est.)	2.61 per ton
Incineration	4.75 per ton
Total	$17.08 per ton

During the project period, some revenue was derived from the sale of salvaged metal ($2,398.24) and from the sale of salvaged tires ($215.81). When this revenue is deducted from the total 22-month project cost, the net total unit cost of disposal becomes about $16.85 per ton.

Productivity of Inmate Labor. An analysis of the productivity of prisoner labor in a project of this type necessarily must be subjective. Although the number of prisoners assigned to the project nowmally ranged from 28 to 37, those actually engaged in productive labor usually would be no more than half of those present. The remainder, even if given specific work assignments, were essentially non-productive. Even those prisoners doing productive work were, with a few exceptions, not effective in achieving high productivity. Further, they are available for work only 6 hours per day, and often even less.

In addition to the low productivity of the prisoners, it was apparent that they had little regard for the property of others. Machinery operated by the prisoners was subjected to extreme abuse, resulting in unusually high maintenance costs and excessive down time.

The initial concept of plant operation involved the use of about 25 inmates for the manual labor required for waste wood processing and disposal. Since this operation has not proven to be effective, for the reasons given elsewhere in this report, the processing procedure for waste wood was modified toward the end of the project period.

Bulky refuse processing at the project facilities normally makes use of only four prisoners, utilized to assist regular City personnel in operations. It is estimated that the work currently being done by the inmates could be performed by three regular personnel, and if this were done, the two security guards could be eliminated. As an approximation of the relative cost of inmate labor versus regular labor, the following is presented:

Two security guards at an annual cost of:	$16,108.00
Three regular personnel at an annual cost of:	22,224.70
Difference in personnel cost	$ 6,116.70

Superficial scrutiny of these figures indicates some economic advantage in utilizing prisoner labor. However, it must be recognized that inmate labor is available for only 6 hours per day compared to 8 hours per day availability for regular labor. In addition, the operational problems which have occurred with the use of inmate labor have shown other, more indirect, disadvantages in using such labor. It also is possible that with a revision to the outlet conveyor from the mill, one man could be eliminated from the work force presently required.

This modification consisted of splitting only logs which were 12 inches or less in diameter, and shredding the resulting smaller pieces. Logs larger than 12 inches in diameter are disposed of by sanitary landfill.

EVALUATION OF PROJECT WORTH

TANGIBLE VALUE

Positive Features. The project has demonstrated that size reduction of bulky refuse can be successfully accomplished by the use of appropriate shredding equipment. The volume of raw bulky refuse can be reduced some 40 to 50 per cent by shredding. In addition to volume reduction by shredding, it has been found that shredded bulky refuse may be incinerated in a municipal incinerator, by mixing the shredded material with unshredded refuse, without significantly affecting incinerator plant operations.

The construction of a plant for disposal of bulky refuse has provided a systematic method for disposal of this waste. All the bulky refuse collected by City agencies is brought directly to the plant. The availability of a single collection point, to which large quantities of bulky refuse are delivered daily, has encouraged prompt disposal of such wastes by individuals, and has permitted the reclamation of substantial quantities of salvable metal. During the project period 996 tons of metal was reclaimed from bulky refuse.

The project also demonstrated that marketable wood chips could be produced from the waste wood generated in cities.

Negative Features. The project failed to provide a complete solution to the City's waste wood disposal problem. One of the primary objectives of the plant was to provide an acceptable method of waste wood disposal. The major problem encountered in attempting to dispose of waste wood was the inability to split the larger logs into 8-inch diameter pieces. The hydraulic log splitter, installed for the purpose of splitting the large logs, was not capable of splitting many of the larger logs. (See "Observations on Equipment Performance.") The log splitter also has a very slow operating cycle, and even if the machine were capable of splitting all logs it would provide only approximately 20 per cent of the splitting capacity required to perform the work load for the City of St. Louis. The City is currently investigating alternate methods to accomplish size reduction of large logs.

During the project period, approximately 20 per cent of the City's waste wood was disposed of at the plant, and it was necessary to landfill the remainder.

The bulky refuse and waste wood disposal plant has proven to be a costly endeavor. Disposal cost for only maintenance and operation of the plant has amounted to $9.72 per ton of processed material. After the bulky refuse has been processed at the plant, it is taken to the City incinerator for disposal, incurring an additional 4.75 per ton in incinerator disposal cost. If the

project had been financed entirely with local funds, it is estimated that the amortization cost of the plant and equipment would be on the order of $4.78 per ton. Taking into consideration all of the above cost elements, the disposal cost per ton adds up to $17.08.

INTANGIBLE VALUE

One of the objectives of the project was to demonstrate the feasibility of assisting in human rehabilitation of City Workhouse Inmates. The Warden in charge of the Medium Security Institution has indicated the project to be of value to the inmates. There has been a satisfactory response from those inmates assigned to the project, although they are utilized primarily for heavy, dirty manual labor. The opportunity to be outdoors and away from confinement appears to be appreciated. Since the beginning of the operations, no inmate has refused to work at the facilities. The inmates appear to be interested in the machinery and its operation. To a limited degree, the project has been of benefit to the inmates in observing and assisting in the operation of equipment they had not seen before.

ALTERNATE DISPOSAL METHODS

Landfill is the only alternate means for disposal of bulky refuse existing in the St. Louis area at this time. Although the dumping fees at the remaining landfills have increased sharply in the past few years, it is still more economical to dispose of bulky refuse by landfill than by shredding and incineration. During the summer of 1971, the quantity of bulky refuse delivered to the plant for disposal increased sharply, as described previously in this report. By July of 1971, the City was forced to begin supplementing the shredding plant disposal method by landfill. From July of 1971, to the end of the project period, 3,565 tons of bulky refuse was landfilled. The average cost per ton for landfilling this bulky refuse was $7.80/ton.

PLANT IMPROVEMENT RECOMMENDATIONS

Personnel. Plant operation would be improved substantially by replacement of the inmate labor force with regular employees. The inmates are available for work at the plant a maximum of six hours (and often less) each day. The work schedule as set up for the inmates by Medium Security Institution personnel is as follows:

Report to Work	8:00 a.m.
Lunch Break	11:00 to 11:30 a.m.
End of Work Day	2:30 p.m.

Institution authorities have found it difficult to adjust the schedule in order to obtain longer working hours, contending that a change in schedule would disrupt their inhouse operations. The use of regular employees would allow plant operations to be maintained for a full 8-hour day. The waste wood disposal phase of the project has, for the most part, proven to be ineffective, and, as a result, the need for inmate labor is limited. As the project currently stands, three regular employees could perform the work now being done by the inmates.

The inmates are difficult to control and require constant supervision when assigned to work details. The two security guards assigned to the project to effect control and supervision of the inmates have found it difficult and even impossible at times to motivate the inmates.

The inmates who are kept at the Medium Security Institution are serving terms from 30 days to 12 months. The majority of inmates receive time off their sentence for good behavior, which means that a 12-month sentence is usually reduced to less than 9 months. The short terms of the inmates results in a very high turn-over of the plant labor force.

It has been found that inmates are prone to abuse any equipment they are allowed to use, or operate. Hand tools usually become broken or damaged and turn up missing after relatively short periods of use by inmates. Machinery operated by inmates has suffered extreme abuse, resulting in unusually high maintenance cost and equipment down time.

The problems cited in using inmate labor often creates an atmosphere of confusion and disorganization at the plant. As a result, it has been very difficult to maintain a normal routine method of plant operation.

Equipment. Improvements to the equipment and facilities at the disposal plant could be effected in several areas.

The waste wood disposal phase of the project has been severely hampered by the difficulties experienced in reducing large diameter waste logs to small pieces 8 inches or less in diameter. Once the large waste logs are reduced to pieces with a diameter of 8 inches or less, they may be either sold as pulpwood or milled in the plant shredder and disposed of in the City Incinerator. The machine provided to accomplish the diameter reduction of the large logs is a hydraulic log splitter. The log splitter has proven to be inadequate, lacking both the capability to split many logs and the capacity to keep up with the work load.

In order to improve the plant's ability to dispose of waste wood, some means of effecting size reduction at a rate of at least four tons per hour must be developed.

Some means of exercising better control of material entering the shredder would be desirable. The bulky refuse is currently being fed into the machine with a track-type front end loader. This method of feeding the shredder causes surge loading, and also makes detection and removal of items which cause physical damage to the shredder difficult.

The existing installation was designed to utilize manual labor for loading the feed conveyor, and for safety, the feed conveyor is located above the ground surface. It would be possible to install paving and ramps for the purpose of permitting the front-end loader to push material onto the feed conveyor, thereby creating a somewhat more uniform feed rate.

Another means of improving the flow of material into the mill would be to install a vibratory conveyor in a position to act as the primary receiving conveyor for raw bulky refuse. The vibratory conveyor could be fed with a front end loader, and the action of the conveyor would cause the bulky refuse to be metered, at a relatively uniform rate, on to the belt type shredder feed conveyor. The transfer point from the vibratory conveyor to the mill feed conveyor would then be a good location to effect monitoring for detection of material which may prove harmful to the shredder.

The shredder used to grind bulky refuse should be made larger and heavier. The shredder currently in use experiences severe shock loading when such items as household appliances are milled. The severe operating conditions imposed upon the shredder have caused internal damage to the machine on three different occasions. The extreme variation in types of material fed into the shredder continuously subjects the machine to wide and sudden loading conditions.

The need for a larger, heavier shredder is also supported by the increased disposal requirements for bulky refuse which has occurred since the inception of the project. The original estimate of the disposal requirements for bulky refuse collected in the City of St. Louis, just prior to building the shredding plant, was 2,000 tons annually. During the calendar year of 1971, 8,689 tons of bulky refuse was brought to the plant for disposal. The quantity of bulky refuse shredded and incinerated during this same period was 5,878 tons. Bulky refuse which was not shredded was disposed of primarily by landfill. Present indicators point to an estimated collection of 10,000 tons of bulky refuse during 1972.

The drainage system in the shredder discharge conveyor pit clogs on the average of once a month. This problem is caused by large amounts of grit getting into the sewer drains.

The grit is the result of having to use a sprinkler in the shredder to quench hot metal particles being discharged in the milling process. It has been found that the sprinkler system in the shredder must be set at a fairly

high discharge rate to ensure adequate quenching. If the hot metal particles are not cooled by quenching, they will cause fires in the combustible milled refuse. The problem of grit getting into and clogging sewer lines would be alleviated by incorporating a sump type drain into the system. The sump would require cleaning periodically, but would prevent the grit from gaining access to the smaller drains.

The value of the shredding operation would be increased by installation of a magnetic separator to remove ferrous metals from the milled refuse. During the course of the project, it was proposed that a magnetic pulley be installed in place of the head pulley on the discharge belt conveyor. The proposal for providing the magnetic separation feature was defined as being beyond the original scope of the project, hence the device was not installed.

The discharge sliding belt conveyor has proven to be inadequate as a means of handling the shredded bulky refuse. This conveyor should be replaced with a troughed belt conveyor with a greater belt speed and a shallower slope. Further, the transfer point between the vibrating discharge conveyor beneath the mill and the belt conveyor should be improved.

PROJECT IMPACT ON ST. LOUIS

The Bulky Refuse and Waste Wood Disposal Project has had a significant impact in the area of bulky refuse disposal. When the plant was first placed into service in June of 1970, it was estimated that 2,000 tons of bulky refuse would be processed annually. During the first seven months of plant operation, from June through January of 1970, 2,040 tons of bulky refuse was delivered to the plant for disposal. As time went on, the information that the City was operating a facility which would dispose of bulky refuse became common knowledge, and generated considerable interest. The idea that there existed a specific and accessible place to dispose of bulky refuse in the City appealed to many civic-minded groups who were interested in cleaning up their neighborhoods. Clean-up campaigns came into being which had never before existed. City Departments began planning and implementing more intensified clean-up programs. The availability of Federal funds through the Emergency Employment Act and the Model City Agency, made many of these programs reality. During the calendar year of 1971, 8,689 tons of bulky refuse were collected in the City and brought to the plant for disposal. The current indications, based on clean-up campaigns now in progress, point toward a collection of at least 10,000 tons of bulky refuse in 1972.